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SINGLE PHASE MICROCONTROLLER-BASED AUTOMATIC CHANGE OVER SWITCH

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ABSTRACT

Power failure or outage in a country, state or city is highly detrimental to development in public and private industries. The insecurity associated with constant or frequent power failure or outage brings about limitation to power consistent investments, thus hampering the development of industries and multinational ventures. Processes like carrying out surgical operations in hospitals, laboratories which require constant power supply for research, money transactions between banks and more require constant use of uninterrupted power. This research covers the design and construction of a single phase microcontroller-based automatic power changeover. It has the capacity to automatically switch power from national grid to generator and vice versa, once there is power failure in any of the two power supplies. This was achieved by the use of electrical components such as resistors, capacitors, diodes, transistors, opto-isolators etc., integrated circuits that have timing abilities and relays for switching effect. Due to the looping of the pole of the contactor to give 50A current each for PHCN and generator, the maximum power the circuit can withstand on an a.c voltage of 240V is 12KVA. This means the circuit can carry a large amount of power in homes and offices.

KEYWORDS: Changeover Switch, Microcontroller, Contactor, Power Supply, Opto-Isolator

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Original Article

1.0. INTRODUCTION

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The need for constant and stable power supply in a country, state or city cannot be overemphasized. In most developing nations, industries, firms and organizations contest for power supply that is unreliable and insecure, thus marring the effect of productivity and development. In these nations, the quest for secure and reliable power supply remains a dream yet to be achieved. This is as a result of increase in population, industrialization, urbanization (Aguinaga, 2008; Fuller, 2007; Kolo, 2007) and lack of proper planning by the government and utility providers. Most manufacturing industries, firms and institutions such as hospitals and healthcare facilities, financial institutions, data centers and airports to mention, but a few require constant power supply throughout the year. Volatility in power generally delays development in public and private section of any economy (Kolo, 2007; Anon, 2010; Chukwubuikem, 2012). For instance, power failure could lead to prohibitive consequences ranging from loss of huge amounts of money to life casualties (Aguinaga, 2008).

This instability in power supply has led to the development of switching systems between national grid power system and standby generators used as backup. In the past decade, various equipment and configurations have been put in place in order to manage this problem (Aguinaga, 2008). An automatic changeover switching system makes use of contactors, active and passive components and transducers to realize changeover in a shorter

time while excluding human interference and its attendant (Chukwubuikem, 2012).

The research project is designed for power supply applications. It involves automatic change over between the mains power supply and a standby generating set. The project implements an automatic switching or starting of the power generator, whenever the main power fails. The circuit of the project consists of logical control units, display units, alarm units and relay switches. The design of the project takes into consideration practical or real life situations and a lot of precautions were put in place to make its performance acceptable, even though it is a prototype design. The basic operation of the project is to switch ON an auxiliary power supply (a generator). This operation connects the power supply from the generator to the load after a predetermined time interval. This is intended to normalize the current from the generator. Switching is possible through the use of the relays. The system was designed to automatically change power supply back to the main supply moments, after the A.C. mains are restored and to switch OFF the generator.

This project, however is designed and implemented as a micro-processor based controlled system, specifically using the micro-controller as its basic component. It is a dedicated embedded system.

2.0. RESEARCH METHODOLOGY

This research work was carried out using many passive and active electronic components. The design of this project includes the placing of components on Vero boards, soldering and connection of components, test for continuity of components and devices, programming of microcontroller, circuit testing and troubleshooting and result analysis. This circuit was first simulated using Proteus 7 electronic simulation software before constructed and the programme was written using MIDE compiler software. A block diagram of the single phase microcontroller based automatic changeover switching system and a flow chart of the circuit design process is shown in figure 1 and figure 2, respectively, while a study of each of the units present in isolation and when connected together is explained in details in the following section. Figure 3 shows the schematic circuit diagram of the single phase microcontroller based automatic changeover switch that was designed.

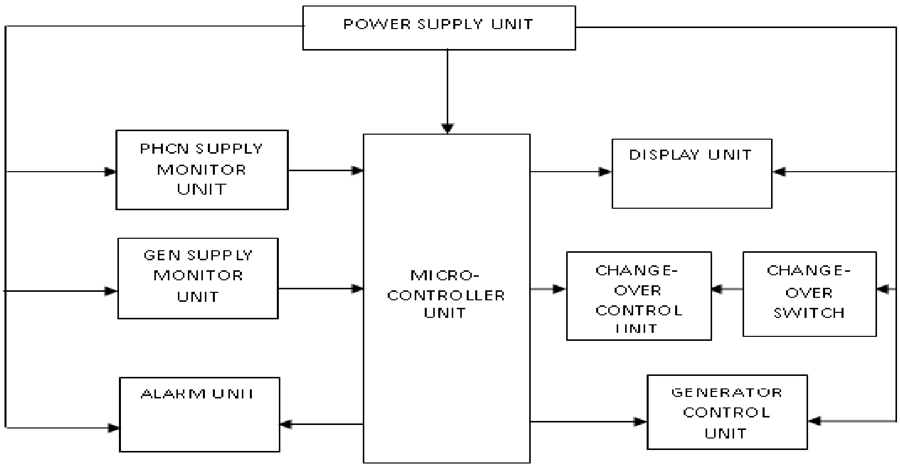

Figure 1: Block Diagram of the Single Phase Microcontroller Based Automatic Changeover Switch

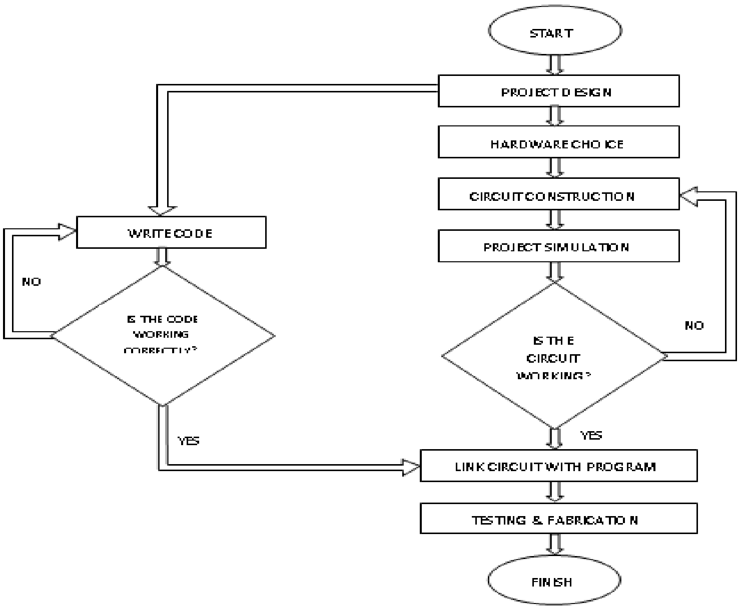

Figure 2: Flow Chart of Circuit Design

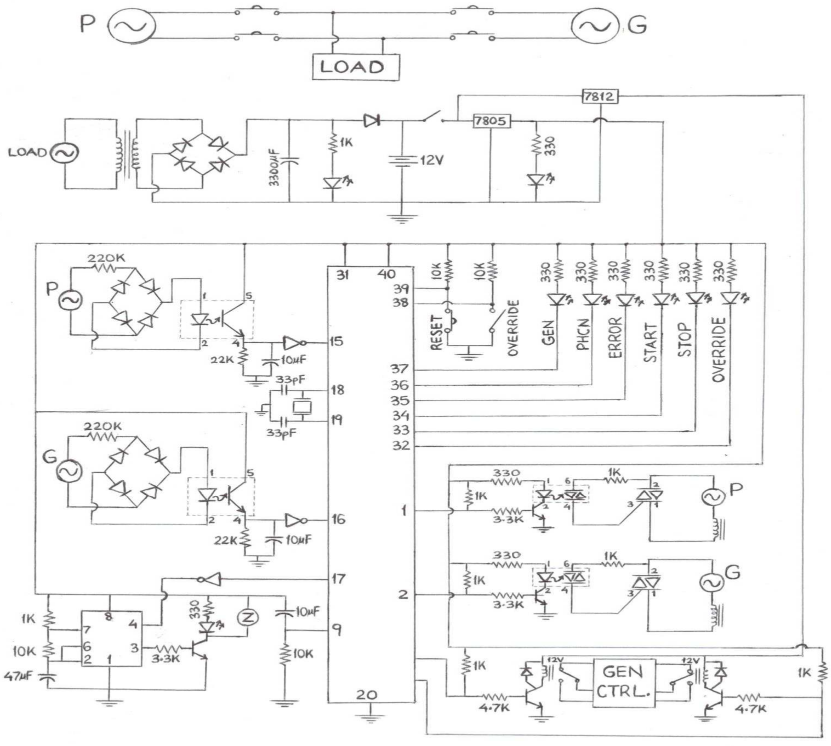

Figure 3: Circuit Diagram of Single Phase Microcontroller Based Automatic Changeover Switching System

3.0. CIRCUIT ANALYSIS AND CALCULATIONS

In this section, each of the unit making up the circuit is explained in details: from the power supply unit to the microcontroller unit to the display to the generator control unit to the alarm unit up to the last unit of the circuit.

3.1. Power Supply Unit

A rectifier circuit is one that converts ac power from the source at the 220/240 Volts, 50 Hz to a dc voltage of any

level. The output current is a function of the current of the transformer and the current demand of the circuit. The DC voltage required by the automatic control for the domestic appliances control circuit is 12V dc and 5V dc. The relays will be powered with the 12 Volts while all other circuits will be powered by the 5V. Naturally, the design calculations were done using 12V and the values of the components are chosen as follows:

T1: This is the step down transformer. The required dc voltage for the circuit is: 12volts/600mA, thus the transformer (T1) chosen is: 12Vac/1000mA.

D1-D4: These are rectifier diodes. The diodes chosen must have a peak inverse voltage that must be able to withstand twice the peak voltage (V_p) and the total forward current of the transformer output.

$$V_p = \sqrt{2}\ V_{rms} \tag{1}$$

Where V_p is the peak voltage of the transformer output.

V_{rms} is the actual output voltage from the transformer = 12Vac

DC forward current = 1A (the diode chosen is the 1N4007)

Consequently, D1-D4 = IN4007

C1: This is the filter capacitor (electrolytic) and it comes with a capacitance and a voltage rating.

Voltage Rating

The voltage of the capacitor must be able to withstand 1.5 times the output voltage of the diode.

$$V_{Dp} = V_p - V_D \tag{2}$$

Where V_{Dp} is the output peak voltage from the diodes.

V_p is the peak voltage of the transformer

V_D is the voltage drop of the diodes (0.7 x 2)

Therefore

$V_{Dp} = 16.97V – 1.4V$

$V_{Dp} = 15.57V$

$V_C = 1.5 \times V_{Dp}$

Vc is the voltage rating of the capacitor

Vc = 23.6V

Capacitance Rating:

The capacitance of the capacitor must be such that it could reduce the ripple voltage (V_R) to about 30% of the output peak voltage from the diodes.

$$V_R = 30\% \text{ of } V_{Dp} \tag{3}$$

$V_R = 4.67V$

From the ripple voltage equation, we could get the capacitance

$$V_R = \frac{I_{max}}{2fC} \qquad (4)$$

Where V_R is the ripple voltage

I_{max} is the maximum current from the diodes/transformers

f = the frequency of supply

C = the capacitance of the capacitor in Farads.

From previous calculations,

I_{max} = 1000mA, f = 50Hz, V_R = 4.67V

$$C = \frac{1000 \times 10^{-3}}{4.67 \times 2 \times 50}$$

C = 2.141 x 10^{-3} F

C = 2141.32 μF

This value cannot be obtained in the market so the next capacitance value is chosen. Therefore the capacitance to use is 2200μF /35V, though in this work, 3300μF/50V was used as it was the closest gotten during the time of construction.

3.2. Microcontroller Unit

The microcontroller unit circuit is the heart of the project. This is where; the program for the control part of the project is written and burned using assembly language and a universal programmer, respectively.

The 8052 microcontroller hardware circuit is usually a very flexible one, and all the surrounding components are given a recommended range of values, by the datasheet but the actual values can be chosen by the programmer.

For the programming of the microcontroller for the automatic changeover switching system, the chosen values are as follows:

- Reset capacitor (C_1): 10μF
- Reset resistor (R_1): 10 KΩ
- Crystal oscillator (X_1): 12MHz
- Crystal capacitors (C_2 & C_3): 33pF
- Pull-up resistors (R_5 to R_9): 1 KΩ

3.3. Display Unit

This unit shows the status of the system. It serves as an interface between the user and system. It consists of light emitting diodes (LEDs) and current limiting resistors (6 each). The value of each current limiting resistor is calculated using the following equation:

$$R_x = \frac{V_S - V_D}{I_D} \quad (5)$$

Where R_x = current limiting resistor, V_S = Supply voltage (5V), V_D = Diode voltage (2V) and I_D = diode current (10mA – 20mA).

NB: The more the current, the brighter the LED; thus, the shorter the lifespan and vice versa.

Therefore, $R_x = \frac{5V - 2V}{10mA} = 300\Omega$

We have thus used a resistance of 330Ω as the value of current limiting resistor.

The power consumed by one LED is:

$$P = IV \quad (6)$$

P = 10mA x 5V = 0.05VA

Therefore, for 6 LED's, the power consumed is 6 x 0.05VA = 0.3VA.

3.4. Generator Control Circuit

This is the circuit the system uses to turn ON and OFF the generator, in accordance to the program run in Read Only Memory (ROM) of the microcontroller. It consists of pull-up and base resistors, transistors, relays and free-wheeling diodes.

Since the output of a microcontroller has only 2mA source current, the pull-up resistor, R_p aids the current output. This unit is a mirror circuit for starting and stopping the generator. When there is a base current, the transistor goes into saturation and the relay is energized. When base current is zero, the transistor goes into cut-off and the relay is de-energized. The free-wheeling or spike diode provides a path for the stored current in the relay (due to the presence of an inductor) in other to avoid damaging any component. The value of R_B must be greater than R_p (R_B>R_p). Hard saturation occurs when $R_B = 10R_C$, where R_C is the impedance of the relay.

3.5. Alarm Unit

The alarm sounds on four conditions:

- When power fails
- When power is restored
- If a command is given for generator to start and it refuses after the six trials
- If a command is given for generator to stop and it refuses

The circuit consists of resistors, capacitor, LED, 555 timer IC, not gate, transistor and a buzzer. The circuit is basically an astable multivibrator whose frequency, f can be calculated using the following equation:

$$f = \frac{1.44}{(2R_2 + R_1)C_1} \quad (7)$$

For 50% duty cycle, $R_2 = 10R_1$

The DC voltage rating of a buzzer is 3-24V.

3.6. Changeover Control Unit

This circuit consists of contactors, resistors, transistors (BC547), triacs (BT136), and triac-based opto-isolator (MOC3021). A contactor is a mechanical switch just like the relay but carries larger current. A relay has a current rating of 30A (220-240V), single pole and is energized with dc, while a contactor has a current rating of 100A (415V), four poles and is energized with ac. The triac is a noiseless static relay (no moving parts) and generates less heat. They are more expensive than relay and does not work with dc only ac. Microcontrollers cannot directly control the triac, hence the need for a triac-based opto-isolator.

R_x is the biasing resistor which is a series combination of a 360Ω and 470Ω resistor according to the datasheet of the triac used. Hence we have used a 1k resistor for R_x. R_C is 330Ω as calculated during the analysis of the display unit, R_B is 3.3k ($10R_C$) while R_P can take any value from 470Ω-22kΩ.

3.7. Changeover Switch

This is the unit responsible for changeover between PHCN supply and generator power. Since a contactor has four poles of 25A current each, two poles were looped to get a current of 50A for the PHCN and generator phase. Thus, the maximum power the contactor can withstand for a 240V a.c supply is:

$$P = IV$$

$$P = 50A \times 240V = 12KVA$$

3.8. Gen/PHCN Supply Monitoring Unit

This circuit monitors the type of power source that is available for use and feeds the microcontroller for changeover to be effected. It consists of resistors, rectifier diodes, transistor-based opto-isolator (4N35) and a NOT gate (CD4069).

When a power source is available, the voltage is rectified and the LED in the transistor-based opto-isolator is forward biased, therefore putting the transistor in the same IC into saturation. The NOT gate is connected to microcontroller which take action as implemented by the program. R_E is a pull down resistor varying from 470Ω – 22kΩ. The LED in 4N35 has a forward diode current of 1mA and R_C has a value of 220k ($10R_E$).

4.0. RESULTS AND DISCUSSIONS

Table 1 below, gives the performance description of some parameters considered during and after the construction of the single phase microcontroller based automatic changeover switching circuit.

Table 1: System Results

Parameter	Performance
Switching speed	< 6seconds (adjustable)
Load capacity	< 12 KVA
Buzzer alert	>70 Decibels
Input voltage (<=240V)	Output voltage (<=240V)
Power supply	5V, 12V

Figure 4: Constructed Circuit

The circuit in figure 4 is one that would automatically turn on a generator when public power supply fails, and automatically change over the source of power supply to the load to generator power. When public power is restored, it sounds an alarm for a while to verify if the power is steady, then it changes over back to public power supply and shuts down the generator. In the event that the generator refuses to start at the sixth trial, the system shuts down and sounds an alarm indefinitely until the reset button is pressed or public power is restored. In the event that the generator refuses to stop, the system sounds an alarm indefinitely until the reset button is pressed. The function of the LEDs in the display section of the constructed circuit is given in the table below:

Table 2: Functions of the LEDS on Display

Light Emitting Diodes (LEDs)	Functions
Mains	Comes on whenever public power supply is available
Power	Comes on whenever generator power supply is available
Alert	Comes on whenever either power source is available
GEN ON	Comes on when running on generator power
PHCN ON	Comes on when running on public power
Error	Comes on whenever there is a fault on the system
GEN start	Comes on when the system starts the generator
GEN stop	Comes on when the system stops the generator
Override	Comes on whenever the system is on override

5.0. CONCLUSIONS

In this research work, the simulation and construction of an efficient and cost effective single phase microcontroller based automatic changeover switching system was achieved. This circuit has the ability to accurately monitor the power supply from the national grid of the Power Holding Company and respond appropriately upon a power outage by starting a standby generator to supply power. Upon the restoration of utility power, the system changes the load back to utility and shuts down the generator.

Due to the looping of the pole of the contactor to give 50A current each for PHCN and generator, the maximum power the circuit can withstand or an ac voltage of 240V is 12KVA. This means the circuit can carry a large amount of power in homes and offices. This project saves resources like time, energy and even lives while ensuring automatic and efficient power load sharing from the consumer end. This project does not have any restriction in the aspect of who to use it and who not to use it nor where to use it and where not to use it. Its applications range from domestic homes, light industries and heavy industries.

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